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GEOPHYSICAL VARIABLES AND BEHAVIOR: LXXXVI. GEOMAGNETIC ACTIVITY AS A PARTIAL PARTURITIONAL TRIGGER—ARE MALE BABIES MORE AFFECTED THAN FEMALE BABIES?[1]

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Summary.—The birth dates of 163 men and 245 women who were born between the years 1958 and 1969 were extracted from our data base for first-year university students. Daily aa values, measures of the amplitude of global geomagnetic activity, were obtained for the birthdays and for each of the seven days before and after the birthdays. Analyses of variance indicated no significant differences in the magnitudes of the geomagnetic activity during these 15 days; however, men were born when the geomagnetic activity was significantly higher than when the women were born. The effect, which was equivalent to a correlation coefficient of about .20, was largest for the day of birth and for the two or three days before birth. The means of the aa values for the day of birth and the day before birth for the men were about 7 nanoTesla higher than the values for the women.

The perinatal phase of development can be considered a dynamic condition that may be responsive to subtle environmental stimuli. For example, Menaker and Menaker (1959) studied the lunar phase at the time of approximately 500,000 births over a 10-yr. period. The trough-to-peak range in daily births during the lunar month was about 5% of the average and was maximum during the day of the full moon. Because the full moon is frequently associated with increases in geomagnetic activity (Persinger, 1980), correlated with its passage through the neutral sheet of the geomagnetic tail, we hypothesized that this geophysical process might encourage the onset of parturition in near-term mothers. Were this hypothesis valid, people would be born during the 48-hr. to 72-hr. period of increased geomagnetic activity. This would be reflected as increased geomagnetic activity during the days of birth and the one to two days before birth relative to before this interval or to the postparturitional period.

METHOD

Subjects

The self-reported birth dates of 163 men and 245 women, born during the years 1959 through 1968, were obtained from a data base for first-year

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university students who had enrolled in introductory psychology courses. The median age for both the men and the women was 20 years old.

Procedure

Values for the aa (average antipodal) index, a measure of the daily average of the variations in the magnitude for the global geomagnetic activity, were obtained from Mayaud (1973). For each subject these values were obtained on each of the seven days before birth, the day of birth, and on each of the seven days following birth. Because of the heterogeneity of variance between days for the aa values, log base 10 transformations were completed for each of the 15 days. This range of time, seven days before to seven days after birth, was selected on the assumption that any potential effect upon the birth process would be a subtle "triggering" phenomenon. The interval of ± 7 days was considered sufficient to capture this inflection in geomagnetic activity.

Repeated-measures analyses of variance were completed for the raw aa values and for the log transformations of these values. Subsequent to *post hoc* inspection of the results and exploration for the sources of variability, two-way analyses of variance with one level repeated (days) and one not repeated (men vs women) were also completed. Paired t tests and independent (group) t tests were applied appropriately. All analyses used SPSS software.

Results

Repeated-measures analyses of variance yielded no statistically significant differences between the geomagnetic activity during the 15 days around birth as inferred by either the aa values ($F_{14,5684} = 0.79$, ns) or the log transformations ($F_{14,5684} = 0.94$, ns) of these values. When sex was considered as an independent variable, however, the results showed that men compared to women had been born when the geomagnetic activity for this period was significantly higher for both the aa values ($F_{1,406} = 14.48$, $p < .001$; $\eta^2 = .03$) and the log transformations ($F_{1,406} = 11.15$, $p = .001$; $\eta^2 = .03$) of these values. The significant heterogeneity of variance within the matrices between the geomagnetic activity for the period when the men had been born and the women had been born for the aa values ($F = 5.74$, $p < .001$) was reduced to an acceptable value ($F = 1.47$, $p = .001$) following the log transformation.

The means and standard errors of the mean for the aa values (in nano-Tesla, nT) and their log transformations for the 15 days around birth for the men and women are shown in Fig. 1. The repeated-measures analyses of variance also showed a statistically significant interaction between the days around birth and sex for both the aa values ($F_{14,5684} = 2.62$, $p = .001$; $\eta^2 = .01$) and their log transformations ($F_{14,5684} = 1.83$, $p = .01$; $\eta^2 = .004$). *Post hoc* analysis indicated that the source of this interaction was due primarily to the statistically significant increase ($p < .01$) in geomagnetic activity during each of

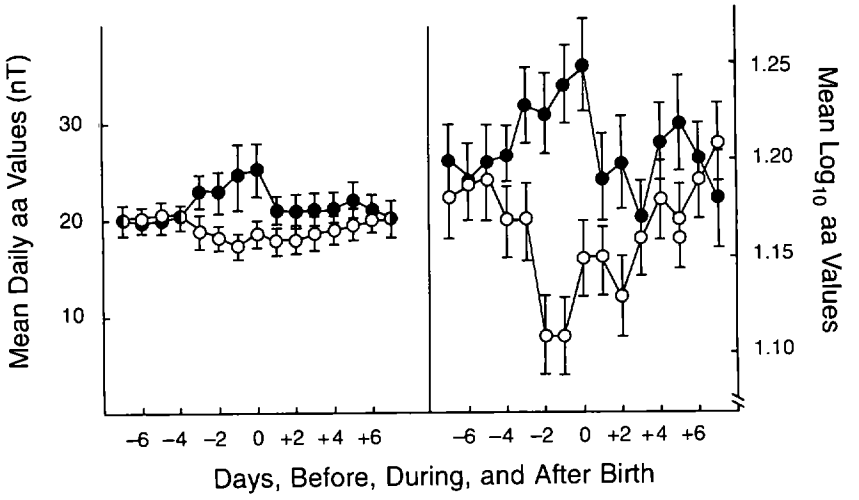

FIG. 1. Means and standard errors of the mean for the daily aa values and their log base 10 transformations for the days of and for each of the seven days before and after the men and women in this sample were born (men, $n = 163$, ●; women, $n = 245$, ○)

the three days before birth ($t_{406} = 2.81$, 3.14, and 3.37, respectively) and the day of birth ($t_{406} = 2.71$) for the men compared to the women but no statistically significant differences in geomagnetic activity were noted for any of the other days.

DISCUSSION

The results of this study did not confirm the hypothesis that people in general are born during or following the days of increased geomagnetic activity. The results suggest, however, that male babies, at least those in this sample, were born when the geomagnetic activity was significantly higher during the day of birth and during the two to three days before birth. The average increases in geomagnetic activity during these three preparturitional days and the birthdays for the men compared to the women were between 4 nT and 8 nT. These values are within the range associated with lunar semidiurnal variations (Matsushita, 1967).

Although the lunar phase during the parturitional period was not analyzed for this sample, the increased geomagnetic activity during the day of birth and the two to three days before birth would be consistent with the role of this geophysical force in the weak but statistically significant full-moon enhancement of births reported by Menaker and Menaker (1959). Bigg (1963) examined geomagnetic data over an 81-yr. period and found that the total numbers of geomagnetic storms ranged between 220 and 240 around the days of the full moon and between 180 and 190 around the days of the new moon. If the entry of the moon into the neutral sheet of the earth's

magnetic tail during the two to three days before a full moon was associated with enhanced geomagnetic activity and it was an environmental component of the triggers for parturition, then a small increase in the proportions of birth during the full moon would be expected.

The observation that male babies compared to female babies were born during a period of enhanced geomagnetic activity suggests a differential sensitivity of male and female fetuses (or their mothers) to proximal stimuli associated with geomagnetic activity. The increased variability of geomagnetic activity, as indicated by the statistically significant tests for homogeneity of variance, around the days when the male babies were born in this study compared to the days when the female babies were born suggests that only some male fetuses responded differently than others to the critical stimuli.

Although increases in the magnitude of daily global geomagnetic activity above 15 to 20 nT have been associated with reduced thresholds for limbic seizures (Michon & Persinger, 1997; Persinger, 1995), symptoms consistent with covert limbic electrical activity (Renton & Persinger, 1998), and reports of increased incidences of vestibular sensations (Persinger & Richards, 1995), direct effects from meteorological factors associated with full moon periods cannot be excluded. For example, Lethbridge (1970) found a significant enhancement of thunderstorm activity during the full moon. We also cannot exclude the possibility that this effect, although statistically significant and of potential ecological relevance, has been confounded by an unknown selection feature that influenced the students' attendance at the university or their enrollment within first-year psychology courses.

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ENGLISH LETTER FREQUENCIES IN TRANSCRIBED SPEECH VERSUS WRITTEN SAMPLES[1]

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Summary.—This study examines the frequency of letters of the alphabet as a function of their origin in writing or in transcriptions of speech. Data were derived from two sources, both in English. One source was from a previous publication and included written and speech samples of approximately 2,400 words each from six subjects. A second source derived from a previous study that developed an estimate of English letter frequencies using a sample of 320,780 words from an article by Whissell (1998). The combined results showed remarkable consistency of English letter frequencies across different types of sources, providing further evidence of the stability of English letter frequencies.

Oral and written language can be depicted as two of many components that occupy a single continuum of communication (Horowitz & Samuels, 1987). As two forms of human communication, oral and written languages alternatively overlap and retain their particular identities. Oral and written languages are socially constructed systems of symbols that we rely on to represent the elements of our experience. Because of the temporal development of these two forms of communication, written language builds on a pre-existing capacity for oral language: young children who are learning to read draw upon their considerable early experiences with oral symbolic systems (Luria, 1983) and perceive print to be a code that is based on speech (Perfetti, 1987). Yet it would be simplistic to state that written language itself is merely human speech written down. For example, written language cannot draw upon the rich features of oral language, e.g., a rising tone, an arched eyebrow, a telling pause, that convey implicit meaning. Written sources consistently reflect complexity of language far exceeding that found in conversation (Chafe, 1985; Cunningham & Stanovich, 1998). The units composing written and oral language also differ: in written language, elements such as an alphabet are the smallest units that relate information, while oral language builds on phonemes. The relationship between these units of oral and written language—letters and phonemes—is the focus of the present study.

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For a number of years, researchers in linguistics and psychology (e.g., Francis & Kučera, 1982; Kučera & Francis, 1967; Thorndike & Lorge, 1963; Whissell, 1998) have devoted considerable attention to detailing the relative complexity of written language by describing word frequencies. The rationale underpinning such exploration is that an understanding of word frequencies has serious implications for development of vocabulary. In a similar vein, examining the frequencies of letters that appear in printed text may benefit our understanding of young children's formal encounters with written words. That is, young children are not typically introduced to entire words in their early instruction; in preschool and kindergarten settings, they are presented independent letters of the alphabet for familiarization. Acquiring knowledge of letters, including decoding, recognizing, and pronouncing letters, and learning how to segment, provides young children with a necessary foundation for learning how to read and spell during elementary school (Treiman, 1993). Indeed, there is evidence that high letter knowledge among kindergarten children can predict later achievements in literacy, although that finding may be mediated by general aptitude (Näslund & Schneider, 1996).

Earlier research conducted by Ridley, Ridley, and Walker (1999) indicated that the alphabetic system of the English language is composed of a remarkably stable set of letters. This research employed a sample of 6,505 words derived by Whissell (1998) that included an accurate representation of English as heard, read, and spoken by a typical English speaker (see Whissell's article for further description of the sample and its composition) as well as a sample of rarer words and a 160-yr.-old estimate of letter frequencies. Over time, across methods of analysis, and irrespective of the rareness of the words sampled, English letter frequencies were found to be quite consistent.

One question that arises from the Ridley, *et al.* (1999) work is derived from the fact that Whissell's sample included transcribed speech. One might argue that it is misleading to collapse the data of transcribed speech (whose original units were phonemes) and written words (whose elements were letters), in essence, to treat the transcribed speech as oral language written down. In the present study, we focused on detailing the differences in letter frequencies between written words and transcribed speech to determine consistency between two types of sources in the original sample. If we found high consistency between the two sources, we could be confident of the merit of our earlier work. If we uncovered a lack of consistency between the letter frequencies of written words and transcribed speech, then we would have to re-examine our previously reported results.

Method

We relied upon two sources of data for this study. The first was a pre-

viously published article by Ridley and Gonzales (1994). The second source was the previously cited study by Whissell (1998). The two sources had different strengths and weaknesses. The contrast essentially reduced to one of fidelity versus bandwidth. Ridley and Gonzales (1994) used a narrow sample but, as described below, it provided a clear distinction between spoken and written samples. Although narrow, the sample is directly relevant to an exploratory study of the issue. The second source was consulted to provide confirmation of the first. While the Whissell (1998) sample provided breadth, it lacked some precision for the particular issue that we addressed.

Ridley and Gonzales's data (1994) derived from the tapes and papers of six individuals who are well known in the field of educational assessment. Written and transcribed speech samples of each individual were selected, for example, articles and conference presentations. Individual samples were limited to 400 words of connected text or transcribed speech. Combined over individuals, the samples of transcribed speech and published text consisted of 4,800 words, 2,400 in each category. For the present article, a few real numbers were eliminated from the sample, reducing the sample size to 2,393 and 2,378 for spoken and written samples, respectively.

The methods used by Ridley, *et al.* (1999) were essentially repeated and applied to Ridley and Gonzales's data (1994). First, for each sample we parsed the words into letters and characters to calculate the total letters and frequency of each letter. The total number of letters plus other characters was the summation over the distinct words of all the products of the word lengths, measured in characters, times the number of times the word occurred. These totals were 12,603 characters in the written sample and 10,839 characters in the speech sample. Reducing the number by the approximately 0.5 to 0.6 percent nonletter characters resulted in totals of 12,543 and 10,770 letters in the two samples. Placing individual letter components of words into adjacent spreadsheet cells, we performed column-wise sorts on letter position to facilitate calculations of letter frequencies. This method resulted in letter totals equal to those derived globally, thereby confirming internal accuracy.

Given the results derived from the first source, we examined Whissell's data for confirmation. Whissell's parsimonious sample used 350 samples, 250 of which Whissell termed "media" sources and 100 "nonmedia" sources. The first type of source included printed sources such as novels, texts, and magazines, plus material converted into print from television. The second type of source emphasized the language that ordinary people use in their daily lives, including their commentaries and discussions. Forty-eight percent of the latter material consisted of transcribed discussions among lay people.

From the data provided by Whissell, the frequencies for words that were originally written and for words that were transcribed from speech

were not distinguished. However, Whissell's categorization of media and nonmedia sources provided a reasonable approximation since only the nonmedia sources included some samples that were transcribed from original oral speech. Of 100 nonmedia sources, 48 sources (48%) were transcripts. Of the 250 media sources, 33 sources (13%) were from television scripts. Although the latter sources conveyed auditory rather than visual stimuli, the origin of this material was first of all written or scripted. Thus, 100% of the media sources originated from published material and 0% from transcribed speech.

In addition, we argue that the fit between Whissell's categories and the distinction of speech versus writing is somewhat closer than the difference between 48% and 0% might suggest. The remainder of the material captured in Whissell's nonmedia category was not published. These written samples conveyed informal everyday activities that suggest closeness to speech rather than formal text. It is difficult to find samples of text and spontaneous speech that are totally uninfluenced by the psychological processes of the other form of communication. People often write from inner speech; spontaneous conversation may be rehearsed or almost edited. However, the second source was a useful supplement since its classification scheme placed transcribed speech or informal writing entirely on one side. It also provided broad representation of English as it is commonly read, heard, and spoken.

Data provided by Whissell includes frequencies for all 6,505 words in the parsimonious sample. From that basis, letter frequencies were determined and reported by Ridley, *et al.* (1999); however, the data also include separate frequencies of each word from media and nonmedia sources. Thus, letter frequencies from each type of source were calculated by partitioning the earlier totals according to type of source.

Results and Discussion

Table 1 presents the results from Ridley and Gonzales's data (1994). Cell contents include the frequencies and percents of each letter organized according to the frequencies found in the written samples. An examination of the table shows an apparent high consistency between the two sets of frequencies. We found a Pearson correlation of .99 between the frequencies in the two samples (published writing and transcribed speech); a Spearman's rank coefficient was also high ($\rho = .98$).

Table 2 displays, for each letter, the frequencies and percents from Whissell's media and nonmedia sources. The letters are arranged in descending order of frequency as found in Whissell's 6,505-word parsimonious sample. Again, the columns of the table reveal strong consistency of letter frequencies and percents across sample classifications. This consistency was confirmed in two ways. First, we found a Pearson correlation of .99 between

TABLE 1
ENGLISH LETTER FREQUENCY AND PERCENT IN WRITTEN AND SPEECH SAMPLES*

Letter	Written Samples		Transcribed Speech Samples	
	f	%	*f*	%
e	1,539	12.27	1,334	12.39
t	1,288	10.27	1,205	11.19
a	990	7.89	896	8.32
i	986	7.86	806	7.48
o	963	7.68	835	7.75
n	907	7.23	858	7.97
s	874	6.97	820	7.61
r	757	6.04	557	5.17
h	497	3.96	514	4.77
l	486	3.87	327	3.04
d	451	3.60	411	3.82
c	430	3.43	261	2.42
u	391	3.12	291	2.70
m	359	2.86	266	2.47
f	294	2.34	196	1.82
p	293	2.34	187	1.74
g	222	1.77	205	1.90
y	180	1.44	175	1.62
w	177	1.41	213	1 98
v	152	1.21	116	1 08
b	131	1.04	148	1 37
k	67	0.53	101	0.94
q	46	0.37	17	0.16
x	33	0.26	18	0.17
j	17	0.14	13	0.12
z	13	0.10	0	0.00
Total	12,543	100.00	10,770	100.00

*Ridley and Gonzales (1994).

the frequencies in the two independent samples (media and nonmedia); a Spearman's rank coefficient was similarly high ($\rho = .99$).

As our results indicate, there is a striking consistency between the English letter frequencies found in the samples of written words and transcribed speech. It is true, as a reviewer pointed out, that there are significant differences between sources when the focus is on certain individual letters, and that these differences may be of interest for some research purposes. However, when the inquiry concerns, as ours did, the whole alphabet, the major conclusion is one of a high order of consistency. The first source provided the most direct evidence of this consistency, while the second provided confirming evidence comparing samples containing some transcribed speech with written samples. At least in terms of the present research, we can treat the written words and transcribed speech as comparable sources of

TABLE 2
ENGLISH LETTER FREQUENCY AND PERCENT IN NONMEDIA AND MEDIA SAMPLES FROM WHISSELL (1998)

Letter	Total Parsimonious Sample		Media Samples		Nonmedia Samples	
	f	%	*f*	%	*f*	%
e	164,253	12.46	114,448	12.40	49,805	12.60
t	125,003	9.48	86,936	9.42	38,067	9.63
o	108,263	8.21	76,286	8.27	31,984	8.09
a	105,122	7.97	75,242	8.15	29,880	7.56
i	91,686	6.96	62,665	6.79	29,021	7.34
n	90,528	6.87	63,229	6.85	24,299	6.91
h	81,241	6.16	56,819	6.16	24,422	6.18
s	79,679	6.04	56,180	6.09	23,499	5.95
r	72,407	5.49	52,649	5.70	19,758	5.00
l	52,462	3.98	37,159	4.03	15,303	3.87
d	52,245	3.96	36,581	3.96	15,664	3.96
u	36,177	2.74	25,590	2.77	10,587	2.68
m	34,084	2.59	23,090	2.50	10,994	2.78
w	31,969	2.43	21,694	2.35	10,275	2.60
c	31,876	2.42	23,440	2.54	8,436	2.13
y	29,062	2.20	19,883	2.15	9,179	2.32
g	28,681	2.18	19,038	2.06	9,643	2.44
f	28,457	2.16	20,557	2.23	7,900	2.00
p	22,547	1.71	15,321	1.66	7,219	1.83
b	19,752	1.50	13,904	1.51	5,848	1.48
k	13,376	1.01	8,664	0.94	4,712	1.19
v	13,069	0.99	9,089	0.98	3,980	1.01
j	2,790	0.21	1,984	0.21	806	0.20
x	2,162	0.16	1,536	0.17	626	0.16
q	773	0.06	616	0.07	157	0.04
z	496	0.04	362	0.04	134	0.03
Total	1,318,160	100.00	922,962	100.00	395,198	100.00

English letters. We maintain that at least two implications stem from this finding.

First, it may be that researchers interested in creating a richer array of data to study the appearance of English letters can incorporate transcribed speech into their sample. Given the complexity of today's communication environment, this integration makes sense. Interesting and new combinations of words from media and nonmedia sources confront us every day through new and emerging technologies. To continue to treat written words and transcribed speech as two distinct and unrelated entities does not reflect the conspicuous overlap that our data indicate or the reality of communication today.

Second, our results suggest that, using English letter frequency as the unit of analysis, at least one aspect of the diverse literacy environments that

surround us can be quite cohesive. Especially with regard to research focusing on children and literacy, emphasis is typically directed at detailing the great differences in demands and skills called for in various literacy environments (e.g., Health, 1983). Previous research has documented the large differences in lexical richness between speech and print (e.g., Cunningham & Stanovich, 1998). At the level of the task, text, and even at the level of the word, then, dramatic discrepancies can be found. Yet the present data suggest that at the level of individual letters, such differences may be less apparent. That is, the variety of letters children confront in textbooks may be quite similar to the array they see as they page through their father's favorite book and as they read transcripts of famous speeches. Educators may take advantage of these parallels in letter frequencies as they continue to develop strategies for facilitating children's literacy.

A natural extension of the present research would be to investigate whether other languages and systems of writing exhibit a similar concordance between written words and transcribed speech. Parallel results might indicate that humans have somehow created written systems which complement oral communication. Discrepancies among different languages and writing may suggest cohesion between the two forms of communication is unnecessary. In any event, the relationship between written words and transcribed speech is made even more complex by our observation that similar English letter frequencies can be found in samples of both forms of communication.

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